



Universal Vacuum System for Chip Ion Traps



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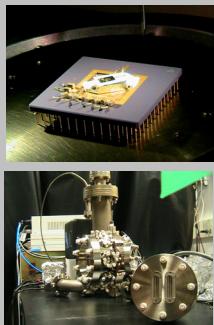
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Universal Vacuum System

The Need for a New System

Vacuum Systems for traps have been custom made for each new trap. However, this starts becoming impractical for many electrode systems and microfabricated ion traps¹ due to the large number of wires to be connected to the trap and to vacuum feedthroughs.

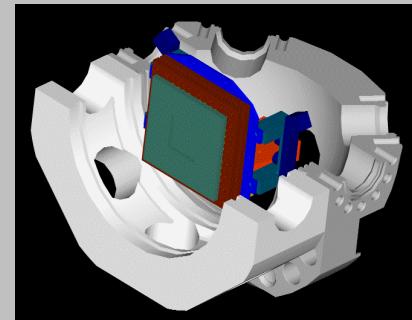


- Mount the trap on a ceramic pin grid array (CPGA) chip carrier, and use a UHV compatible socket.
- Two 25 pin plugs on feedthrough allow a compact and easy way to connect to the trap.

(Top Left) Surface-electrode ion trap mounted on a chip carrier. (Bottom Left) Vacuum System showing the two 25 pin feedthroughs. (Right) 3D model of the system.

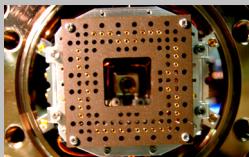
A Modular Design

- Trap mounted on chip makes ion traps swappable.
- Socket can be separately mounted in a hemisphere for symmetric through-hole traps, an octagon for asymmetric surface-electrode traps, or an octagon/hemisphere combination that accommodates both geometries.



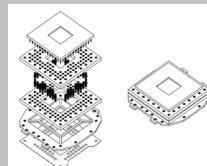
[1] D. Stick, et. al. *Nature Physics* **2** 36 (2006)

Custom UHV-Compatible Socket



- Socket is made out of two plates of DuPont Vespel, a UHV compatible plastic, sandwiching the CPGA receptacles.

• Receptacles are annealed in a Nitrogen box at 450°C for about 1 minute. During annealing, there is a 16 mil steel rod through the receptacle to open the BeCu clips.



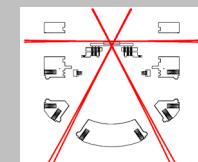
Above: The socket mounted on the plate in the hemisphere. Left: Expanded schematic detailing the socket and construction

Beam Access through the System

- The socket has a wide through hole that enables laser access for symmetric through-hole ion traps.



- Socket is raised into an octagon, which enables beam access for surface-electrode ion traps.



(Top) Looking through a viewport on a hemisphere, one can see beam access for symmetric traps. (Bottom Left) Schematic of trap (in black) and lasers (red). (Bottom Right) Looking through a viewport on an octagon, one can see beam access for asymmetric surface-electrode ion traps

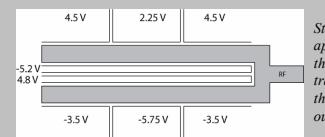
Surface-Electrode Trap

Geometry

- 4 electrode rails and 2 sets of segmented electrodes
- The segmented electrodes provide axial confinement.
- Inner electrode rails and outer segmented electrodes rotate the principal axes⁴.

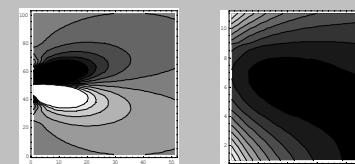


Static DC voltages applied to trap, such that there will not be transverse DC fields that will push the ion out of the RF node



Simulations

- 140V RF at 30MHz
- Depth 0.15eV
- Secular Frequency 11.3 MHz
- RF node at roughly 60 μm above the surface.
- Differential static bias of 10V ($\pm 5\text{V}$) on the center rails rotate principal axes by roughly 10 degrees



The potential from a differential static bias on center electrodes (left) rotates the principal axes of the trap, evidenced by the total potential RF+DC (right)

In the asymmetric ion trap, the broken symmetry means that the electrode voltages have to be carefully tailored such that there are no transverse forces for an ion at the RF node.

Surface trap mounted on a chip carrier, and plugged into the vacuum system.

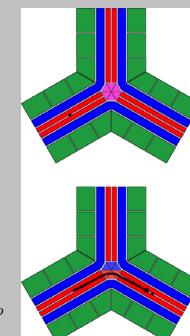
- [2] J. Chiaverini, et. al. *Quantum Inf. Comput.* **5**, 419 (2005)
[3] S. Seidelin, et. al. *e-print quant-ph/0601173*
[4] Private communication, M. Madsen

Future Directions

In the asymmetric surface-electrode trap geometry, we would like to implement multiple trapping zones, and shuttling. Additionally we plan to explore surface-electrode junctions.

Using microfabrication techniques we can create a novel junction that allows us to externally switch track the ion will travel. Like switching railroad tracks, we selectively choose the path of the ion.

Schematic of a novel junction that allows us to selectively choose the ion path



Junction Switching

The junction consists of many segmented pieces that can individually be switched from DC to RF.

- Ion starts in the left channel
- Choosing to shuttle to the right channel, switch upper three electrodes to RF
- The ion should see an RF barrier to the top channel, and trapping to the right.